HEAT REQUIREMENT AS SHOWN BY THE COMPOSITION OF GASES IN A FURNACE USING OHIO COAL RAW.

BY N. W. LORD.

About a year ago I had the opportunity of making a series of analysis of the gas from Buchtel Furnace in the Hocking Valley. The furnace was using principally raw coal at this time, it was working rather cold with a dark and thick cinder and making mill iron. The samples of gas were drawn through a pipe inserted into the down-comer and reaching to its center. Only carbonic acid and carbonic oxide were determined. The "residual" gas consisting principally of nitrogen with small amounts of hydrocarbons, these hydrocarbons were subsequently estimated by calculating from the coal used in this furnace, but as their amounts have no influence on the "heat calculations," actual determination was omitted for lack of time. The samples were drawn at various times during the day as is shown in the following table, where the results and times are given:

	1	2	3	4	5	6
CO_2	5.61	5.0	5.14	5.50	5.23	5.90
CO	32.40	33.3	33.5	33.40	33.0	32.8
Residual gas =	62.0	61.7	61.3	61.0	61.7	61.3

1. 9 a. m., just before cast; 2. 11:15 a. m., just after cast; 3. 1:30 p. m., just after charging; 4. 2 p.m., 10 minutes after charging; 5. 3 p. m.; 6. 3:30 p. m. During flushing, pressure low.

The average of these six analysis, gives: CO_2, 5.39; CO, 33.07; N and CH_4, 61.50. This is the analysis by volume. We may estimate the composition by weight from it by taking the amount of blast (which is calculated further on) and the amount of fuel (coal) used. The coal yields about $3\frac{1}{2}$ feet of "gas" (coal gas) per lb.; this gas is composed of CH_4 and H in about equal proportions; adding these in, the composition of the gas by weight is as follows:

	1	2
CO_2	8.39	9.1
CO	33.00	32.1
CH_4 and H.	2,61	2.9
Nitrogen	56.00	55.9
	100.	100.

No. 2 is the analysis given by Mr. I. L. Bell for the gas from a Scotch furnace using raw coal and roasted black-band ore. The analysis is corrected for the "steam" which Mr. Bell includes, but which here is omitted to bring both to the "dry basis." The agreement between the two shows that my calculated values for CH_4 and H are close to correct.

Before proceeding with this heat calculation it is necessary to have a full statement of the charges and materials used in the furnace; they were as follows: The coal from "mine 21" had the following composition. The analysis was furnished me by Mr. Ed. Orton, jr. and was made on a large and most carefully averaged sample selected from all over the mines, some being taken from every room. The whole was crushed and mixed, and the resulting sample analyzed:

Water	6.30
Vol. Comb	35.75
Fixd Carbon	48.85
Ash	9.10
	100.

Sulphur 1.21 per cent.

There were also using "Eagle coke" with carbon 91.45; ash 8.55. The limestone contained 6 per cent. of silicious matter on the average. The average charge for the 3 days previous, was to the unit of iron made.

Ores	1.468
Scrap	0.058
Cinder	0.454
Stone	0.978
Coke	0.467
Coal	1.747

Iron made per day, 39 tons; blast temperatures about 900° ; F. or 482° C. The carbon per unit of irons made was as follows:

In the coke	0.427
In the coal as fixed carbon	0.853
In the limestone	0.111
Total carbon in furnace per unit of iron	1.391

Deducting from this .035 which is absorbed in the pig iron this total C. is the gases per unit of iron made, was 1.356. If "m" represents the ratio $\frac{CO_2}{CO}$ in the gas then the CO per unit of iron made will be $\frac{77 \times 1.356}{33+21m}$ (Gruner—blast furnace phenomena P. 34). The CO_2 will of course be equal to $M \times CO$. Applying the formulas:

CO in gas per unit of iron $= 2.723 =$ 1.167c
CO_2 in gas per unit of iron $= 0.691 =$ 0.189c

1.356

Bell claims that all the CO_2 given off by the limestone is reduced to CO before it leaves the furnace; Gurner and others say that more of it is probably a middle course will be the safest and I shall assume that one-half is reduced and one-half escapes reduction. In this case to ascertain the best production, that is the heat obtained by combustion, we must deduct from the carbon as CO and as CO_2 an amount equal to that in the limestone one half from each and we will have the C burned to CO and CO_2 in the furnace. Doing this, we have

C burned to $CO = 1.056 \times 2400. =$ 2534.4
C burned to $CO_2 = 0.134 \times 8080. =$ 1082.7

3617.1

The last part of the table gives the heat developed by combustion and is obtained by multiplying each amount of carbon by its calorific value (in the centigrade systen). This figure 3617.1 represents the heat produced in the furnace per unit of iron by the combustion of fuel.

To get the total heat requirement, the heat carried in by the blast must be added. The amount of blast may be accurately calculated by Gruner's formulas. (Op. cit. P. 35.

The oxygen going into the gasses from the ore and flux, will equal 0.673 per unit of iron. The oxygen in the blast per unit of iron will equal $\left(\frac{44+56\,m}{33+21\,m}\right)$ 1.356—0.673.

The corresponding amount of blast will be 6.02; this at 482° C will furnish 667 units of heat, which added to the heat from the fuel combustion will give 4,284.7 as the total heat produced in the furnace per unit of iron made.

This figure will probably fairly well represent the heat requirement of the average run coal furnace of the district considered where as rich an average stock is used; but where the richness of the stock in iron falls off the heat required very rapidly runs up. The following figures give the heat requirements for a number of furnaces. They are mostly taken from Mr. Bell's work on iron smelting and owing to slight differences in the method of considering the limestones are not exactly comparable with the figures above given, but still are so nearly so as to render any conclusion from them sound. They show the great difference between furnaces and indicates the influences of richness of stock and burden of limestone:

	Ore to Ton Iron.	Stone.	Heat Required.
Clarence A........	2.44	0.68	4672
" C........	2.31	0.46	4238
57 foot furnace....	1.96	0.35	4158
70 " "	1.94	0.24	3778
(Buchtel Furnace)	1.98	0,98	4285
North Chicago....	1.58	0 27	3466
Another Ohio Furnace,	1.81	1.18	4633

These difference of course are partly explained by other causes than those referred to; height of furnace, kind of fuel, hardness of ore, etc., but they show how rapidly the heat requirements runs up when the stock becomes poor and hard to flux. There remains the question of economy of fuel in the Buchtel furnace, that is the heat requirement being known and presumably unalterably without change of stock or furnace lines and height. Does the furnace use an excessive quality of fuel to furnish this heat?

If the ore was all reduced by Carbonic oxide and the resulting Carbonic acid allowed to escape from the furnace as such the maximum fuel would be reached if this was done the carbon in the gas as Carbonic acid would be 0.263 units per unit of iron. This would stand for 2125 heat units, and deducting this from the 3617 units, which must be supplied by combustion, there remains 1492 units to be furnished by burning C to CO which would require $\frac{1492}{2400}$=0.621 units of Carbon and the total Carbon required would be C CO_2, .263; C to CO, .621; C in iron, .035; C to reduce ½ CO_2 of limestone, .035; total, 0.974 as against 1.28 now used, a reduction of about 25%. This calculations shows then that the furnace under consideration has about an average heat requirement and that the fuel used is little in excess of that absolutely needed, but not much, as the best practice does not come nearer than 10 or 12% of the theoretical consumption. The real reason for the apparently high fuel consumption is the large amount of tons used, the character of the fuel and the low average richness of the ore.

DISCUSSION.

PROF. LORD:—On the point that has come up in regard to the comparison of producer gas with natural gas by the cubic foot, nobody ever measures producer gas with cubic feet. Producer gas is a mere intermediate between coal gas and furnace gas. Producer gas is simply a means of utilizing coal as a fuel, and in getting at the value of natural gas, I think the comparison should be between natural gas and coal. A pound of natural gas is nearly double the heating power of a pound of coke. The great advantage of natural gas over coal is in the application. Given equal facility of application the coal would have about half the value of a pound of gas. Only remember that in speaking of the comparisons I was alluding to the comparison of coal with gas in weight provided the coal could be as economically used as gas. When we have learned to burn our coal as well as gas we may expect the best results.

MR. ROY:—It is now 10 o'clock, and as we cannot possibly get through the papers to-night, I move that the meeting be adjourned until tomorrow.

Motion seconded and carried.